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MANGANESE MINERALS OF PENNSYLVANIA

By

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ABSTRACT

Manganese minerals occur in Pennsylvania at more than 60 localities. Three localities are known to be commercial possibilities; others may be. The manganese minerals of the State, the nature of their occurrence, and the geology and ore deposits of the three possible commercial areas are described.

MANGANESE MINERALS OF PENNSYLVANIA

By Richard M. Foose

INTRODUCTION

Manganese is the alloy metal most urgently required by the country's iron and steel industry, and it is one of the most deficient in domestic production. In 1940 the United States supplied about 12 percent of its needs of all grades of manganese ore that are used in metal production, and imported 88 percent. Since 1939, an intensive program of exploration for manganese deposits has been carried on by the United States Geological Survey and other organizations.

In the late spring of 1941 the Pennsylvania Geological Survey began an investigation of the manganese minerals of Pennsylvania with a view to presenting complete and accurate information on all the manganese mineral localities in the State, and a detailed description of the geology and ore deposits of all areas that held any promise of commercial exploitation.

This progress report has been prepared with two fundamental ideas in mind: 1. To describe the manganese minerals, how and where they occur, in such manner that the people of Pennsylvania will understand what they are, what their importance is, and will be interested in furthering the knowledge of manganese mineral resources in the State; 2. To describe the geology and occurrence of manganese minerals in Pennsylvania that may have commercial value, including a list of all the known manganese mineral localities. The exhaustive report on manganese minerals in Pennsylvania originally planned will not be published at present; it will include much more field and laboratory information than is now available and a full treatment of the laboratory investigations of the manganese oxide minerals made during the past year.[1]

The area under consideration is the entire State of Pennsylvania. Field work was carried on by the writer continuously from June till October 1941 and additional field investigations were made during the winter of 1941-42. Laboratory investigation of the manganese minerals occupied the months from October 1941 to April 1942. Investigation of many of the manganese minerals occupied the months from October 1941 to April 1942. Investigation of many of the manganese mineral localities of the State was made possible by generous help and cooperation of property owners and interested persons. Special thanks are due Messrs. Harry and James Simon, part owners of the manganese property in Sherman Valley, Bedford County, both of whom gave cheerfully of time and information during the investigation. James Simon aided in the geologic mapping of the area. The author enjoyed the constant help and advise of the staff of the Pennsylvania Geological Survey and the Department of Geology of The Johns Hopkins University. Thanks are due many others, too numerous to mention, who materially aided the investigations from time to time.

[1] Detailed information and additional data are on file at the Geological Survey offices in Harrisburg and may be examined there by interested persons.

Comprehensive work on the manganese minerals of Pennsylvania has not been done previously. The publications of the Second Geological Survey of Pennsylvania have many analyses of iron ores that show manganese content and they mention manganese mineral accumulations at some places. Carpenter [1] and Rogers [2] earlier noted manganese minerals in the State. Penrose,[3] Harder,[4] and Miller [5] summarized the limited knowledge of manganese mineral occurrences in Pennsylvania at different times.

Economics of Manganese Ores

Manganese ore is classified as *battery* ore and *metallurgical* ore. Battery ore must contain more than 50 percent of manganese. Metallurgical ore is all used in ferrous metallurgy and is divided into three classes: *Manganese ore,* containing more than 35 percent of manganese; *ferruginous manganese ore,* containing between 10 and 35 percent; *manganiferous iron ore,* containing between 5 and 10 percent.

The chief manganese products, utilized in the steel industry for the purpose of deoxidation and desulphurization, are *ferromanganese* and *spiegeleisen.* Ferromanganese is an alloy ideally containing about 80 percent of manganese and 12 percent of iron, prepared from high grade metallurgical ores. About two tons of ore prepare a ton of ferromanganese. Spiegeleisen is also an alloy containing approximately 20 percent of manganese and 70 percent of iron, prepared from ferruginous manganese ores. Because speigeleisen can be prepared from many domestic ores not suitable for the preparation of ferromanganese, it has wide application in the present war-expanded steel industry. *Manganiferous pig iron,* a third product used in the steel industry partly replacing the two alloys above, may be prepared from manganiferous iron ore.

Price.—The value of manganese ore depends on mineralogical nature as well as on its purity and manganese content. Prices paid for ores of medium grade, for which the demand is greatest, are relatively stable, but the value of high grade ores (more than 48 percent) fluctuates greatly.

Prices of manganese ore are on a unit basis, in which the unit is one percent of a long ton, or 22.4 pounds of manganese metal. The monthly price quotations for manganese ores may be found in Engineering and Mining Journal. The price of 48 percent metallurgical ore has risen steadily to a fixed price of $1.00 per long ton unit in June 1942.

Salable ore is governed by fairly rigid specifications. For ore carrying less manganese than specified by the buyer there is a penalty of one cent per unit for each percent under the specified amount. There

[1] Carpenter, G. W., Am. Jour. Sci., 1st ser., vol. XIV, pp. 4, 12, 1828.
[2] Rogers, H. D., Geology of Pennsylvania, vol. II, p. 739, 1858.
[3] Penrose, R. A. F., Jr., Manganese; its uses, ores, and deposits: Ark. Geol. Survey, Ann. rept., p. 400-401, 1891.
[4] Harder, E. C., Manganese deposits of the United States: U. S. G. S. Bull. 427, pp. 42, 93, 94, 275, 1910.
[5] Miller, B. L., Manganese occurrences in eastern Pennsylvania: Penna. Topog. and Geol. Survey Bull. 47, 11 pp., 1922.

is a penalty of one cent per unit for each percent of silica (SiO_2) over 8 percent, with the privilege of rejecting ore carrying more than 14 percent silica. No ore should contain more than 0.25 percent of phosphorous, though high-phosphorous ore is occasionally purchased and mixed with low-phosphorous ore. There is no penalty, in most cases, for the iron content.

In 1940 Pennsylvania produced about 1,500 long tons of ferruginous manganese ore, of which 250 tons were shipped to furnaces. There was no production of ore containing more than 35 percent of manganese. No manganese ore was produced in 1941. Twenty-five tons of high grade ore were shipped in June 1942.

Table I shows the available statistics for the production of manganese ore in Pennsylvania.

TABLE I

Production of manganese ore in Pennsylvania in long tons

Year	Manganese ore	Ferruginous manganese ore	Total
1888	22		22
1895	460		460
1896	265		265
1897	354		354
1898		100	100
1899	12		12
1920		150	150
1921		50	50
1922		50	50
1923		150	150
1940		1500	1500
1942	25		25
			3138

MANGANESE MINERALS

More than one hundred manganese minerals are known. These include oxides, carbonates, silicates, and many other compounds. With minor exceptions, manganese oxides are the only minerals found in Pennsylvania.

The manganese oxide minerals are similar to the iron oxide minerals in appearance and may often be mistaken for them. The simplest distinction between the two groups is by color and streak. Most manganese oxide minerals have a black or blue-black color; the iron oxide minerals are more often brown and red than black. A good diagnostic test to distinguish between the two groups in the field is to scratch the mineral on a white porcelain plate or to powder part of the mineral

with a sharp blow from a pointed hammer. The color of the powder on the mineral or the white plate is called the streak. The manganese oxide minerals all possess very dark brown or black streaks. The iron oxide, limonite, makes a yellowish-brown streak and hematite makes a reddish-brown streak. Mixtures of iron and manganese oxides make brownish-black streaks.

Pyrolusite.—Pyrolusite (MnO_2, generally with a little H_2O) is a soft, opaque gray-black to black crystalline or granular mineral. It is so soft that it may be scratched by the finger nail and it soils the fingers with a sooty black smudge. The specific gravity is about 4.8 and the streak is black. It contains 63.2 percent of manganese in its pure form. It occurs as a thin coating on other manganese minerals, as reniform and columnar masses, and has been found at several localities in Pennsylvania.

Psilomelane.—Psilomelane ($MnO \cdot (Mn,K,Ba)O \cdot nH_2O$), is a hard, dense amorphous and partly granular black to steel-blue mineral. It has a submetallic luster, a hardness of 5-6, so it is scratched with difficulty by a good knife blade, a specific gravity of 3.7 to 4.7, and a black to brownish-black streak. The manganese content ranges from 50 to 57 percent because of the indefinite composition and the presence of varying amounts of minor elements like potassium, barium, and water. Psilomelane frequently has a mamillary, botryoidal, stalactitic, or concentric structure that results from a rhythmic accretionary growth. It is also massive, and almost always exhibits excellent conchoidal fracture, the freshly broken surface having the appearance of fractured steel. Psilomelane is the most common manganese mineral in Pennsylvania; actually, several different minerals have the physical character of psilomelane and are so-called.

Manganite.—Manganite ($Mn_2O_3 \cdot H_2O$) is a steel-grey to black crystalline or granular mineral with a sub-metallic to metallic luster. It has a dark reddish-brown or black streak, a specific gravity of 4.2 to 4.4 and a hardness of 4. A knife blade scratches it readily. It contains 62.4 percent of manganese and 10.3 percent of water. It crystallizes in prisms of the orthorhombic system and as wedge-shaped crystals with deep vertical striations. It occasionally occurs as alternating layers with psilomelane in nodular ore.

Wad.—Wad is a soft, dark brownish-black to bluish-black aggregate of manganese oxides, having a specific gravity of about 3. It soils the fingers with a sooty black smudge. The percentage of manganese ranges from 20 to 40 percent. It is fairly common in Pennsylvania and is frequently found associated with the clay and psilomelane in the old iron ore pits of the Appalachian Valley.

TYPES OF DEPOSITS

Factors Influencing Occurrence

Three fundamental factors are largely responsible for determining the place of occurrence of manganese mineral deposits and, in a lesser manner, the nature of the deposits themselves. The factors are stratigraphic, structural, and physiographic.

Stratigraphy.—The importance of stratigraphy in the localization of mineral deposits is evident in many cases. Frequently the resistant and impervious nature of a formation which underlies a more previous and less resistant formation is the decisive factor in causing the precipitation from solution of mineral matter and the accumulation of that mineral matter over a widespread area. This factor has influenced the accumulation of manganese at the base of the Cambrian Tomstown dolomite overlying the Antietam sandstone all along the Great Valley from Northampton County in the northeast to Franklin County in the southern part of the State; it has influenced the accumulation of manganese at the base of the Mississippian Mauch Chunk shale overlying the Pocono sandstone in Bedford and Fulton Counties; it has influenced the accumulation of manganese-rich bogs on the Pocono sandstone in the northern and northwestern tier of counties.

Structure.—The physical position of the rocks, or the structure, is significant in the accumulation and formation of all secondary minerals.

Horizontal and gently dipping sedimentary beds will cause ore-bearing solutions to move slowly down dip or through the strata. Thin concentrations of ore may then accumulate along the dip in some favorable bed. The occurrence of ore in Sherman Valley, Bedford County, is essentially in one bed of shale which dips uniformly 15-20 degrees northwest. Under conditions of horizontal structure, such as exist in the plateau land underlain by Pocono sandstone in northeastern Pennsylvania, the mineral-bearing solutions were "ponded" and caused to disseminate very slowly through the rock pores and along joint and fracture planes.

Less favorable structural conditions than those of flat and gently dipping beds are those created by steeply-dipping monoclinal structures.

Folded rocks frequently create favorable conditions for the accumulation of mineral matter. The synclinal areas of folds serve as natural catchment basins into which mineral-bearing solutions migrate. Combined with a favorable stratigraphic relationship, such as a clay or limestone overlying a hard, resistant quartzite, such an area is favorable for prospecting. Conditions like this exist near the old Reading Banks ore pits southeast of Boiling Springs in Cumberland County, where several synclinal re-entrants of Antietam quartzite, overlain by the weathered Tomstown dolomite, cut into the flanks of the pre-Cambrian South Mountain uplift.

Most favorable of all structural conditions, especially when combined with favorable stratigraphic relations, is that of a basin or a plunging syncline. Mineral-bearing solutions descending into such a structural depression will concentrate there and may deposit a large and rich accumulation of mineral matter such as that at the widely known Crimora Mine, near Basic, Virginia, the largest producing manganese mine in the Appalachian States.

Physiography.—The importance that physiographic conditions can play in the concentration of mineral matter has been shown by Stose

and Schrader.[1] Many of the manganese mineral deposits in the Appalachians are concentrated at definite levels, on the top of or beneath old stream terraces and along mountain benches, which represent old erosion surfaces. The so-called Harrisburg peneplain, a fairly well defined Tertiary erosion surface, which can be traced through a large part of the Great Valley in Pennsylvania, is about at the level of many of the old mountain iron ore pits which extend the length of the Valley. Many of them contain an appreciable percent of manganese. These erosion surfaces are significant because they represent levels to which the land was lowered, involving the removal of many hundrds, and probably thousands, of feet of overlying rocks. It is likely that the removed rocks were the chief source rocks of the manganese minerals. The long period of erosion culminating in crude peneplanation was the time of secondary concentration of the manganese minerals.

Sedimentary Deposits

Only one manganese deposit of sedimentary origin is known in Pennsylvania. A bed of gravel is tightly cemented by black manganese oxide along Roaring Run in Fulton County where it bends eastward to flow through the gap in Sideling Hill at the village of New Grenada. The 6-inch gravel bed is of recent age. It is overlain by a foot of poorly cemented sand and gravel barren of manganese and underlain by a plastic clay one foot thick. The bed dips gently northward. It is not thick enough to have any commercial value. However, deposits of this type, if thick enough, may have real value because the sand and gravel can be separated without much difficulty.

The source of the manganese for this deposit is evidently the ore-bearing basal beds of the Mauch Chunk red shale or the uppermost Pocono sandstone, both of which the stream erodes. Deposits like these can be formed from manganiferous surface waters almost anywhere. Because surface waters do not carry much manganese in solution for long distances, such deposits indicate a close source of manganese minerals, probably a nearby occurrence of some other type.

Hypogene Deposits

With possibly one exception, hypogene manganese minerals in Pennsylvania are only of mineralogic interest; they have no commercial importance. Small veinlets of manganite, which are associated with psilomelane and limonite at Reading Banks, Cumberland County, may be of hypogene origin. Associated as it is with the supergene ore, it has possible commercial importance; alone it has none.

Supergene Deposits

Nearly all the deposits of manganese minerals in Pennsyivania are of supergene origin. Without exception the supergene deposits consist of manganese oxides associated with iron oxides which have been precipitated from descending ground waters carrying dissolved manganese derived from the weathering of overlying sedimentary rocks, and they have accumulated as replacements and associated fracture fillings in lower beds.

[1] Stose, G. W., and Schrader, F. C., Manganese deposits of East Tennessee: U. S. Geol. Survey, Bull. 737, pp. 21, 22, 1923.

Table 2 lists the horizons at which supergene manganese minerals have been found in Pennsylvania, arranged in stratigraphic sequence. It is interesting to note that manganese minerals are limited to the Paleozoic and pre-Cambrian rocks. In the Paleozoic sequence two horizons are most important: The Cambrian period as represented by the Antietam quartzite and Tomstown dolomite of the South Mountain and Great Valley area of southern and southeastern Pennsylvania, and the Gatesburg dolomite of central Pennsylvania. In the Mississippian rocks the most important beds are the Pocono sandstone and Mauch Chunk shale of central and south-central Pennsylvania. The Cambro-Ordovician oxide ore horizons are recognized all along the Great Valley from Pennsylvania to Georgia and Alabama, but the Mississippian horizon is new and entirely different from the manganese oxide deposits in other Appalachian States. It is reasonable to expect that new discoveries will be chiefly at these horizons.

A full description of the nature of ore occurrence at all the horizons listed in Table 2 is impractical for this brief report. Only those deposits having possible commercial value will be so described.

TABLE II

Geologic horizons of supergene manganese oxide minerals in Pennsylvania

Associated rocks	Geologic age of associated rocks
Gneiss	pre-Cambrian
Antietam sandstone	Cambrian
* Tomstown dolonite	Cambrian
* Gatesburg dolomite	Cambrian
Ordovician limestone	Ordovician
Oriskany sandstone	Devonian
Chemung sandstone	Devonian
Catskill redbeds	Devonian
Pocono sandstone	Mississippian
Bogs	Mississippian
* Mauch Chunk shale	Mississippian
Underclay	Pennsylvanian

DITRIBUTION OF MANGANESE MINERALS

More than 60 occurrences of manganese minerals are known in Pennsylvania, the locations of which are shown on Figure 1. Three localities are classed as commercial possibilities. Detailed work has been done in the Reading Banks and Sherman Valley areas; much less work has been done in the Huntingdon Furnace Banks area. It is entirely possible that other occurrences may be found which will be commercial possibilities. At several places exploration is recommended. All occurrences are arranged according to counties; numbers in the

* Best commercial possibilities.

text correspond to numbered localities on the map. No manganese minerals have been observed or reported from 42 counties.

General features of the widespread occurrence of manganese minerals in Pennsylvania noted in Figure 1 are:

1. There are no important occurrences in the Appalachian Plateau province which includes the western, northwestern, and northern parts of the State, nor in the Piedmont and Triassic provinces of the southeastern part of the State.
2. The greatest number of occurrences is aligned in the northeast-southwest trending belt of the Great Valley.
3. The commercial possibilities are limited to the Great Valley and the south-central and central parts of the Ridge Valley province.

TABLE III

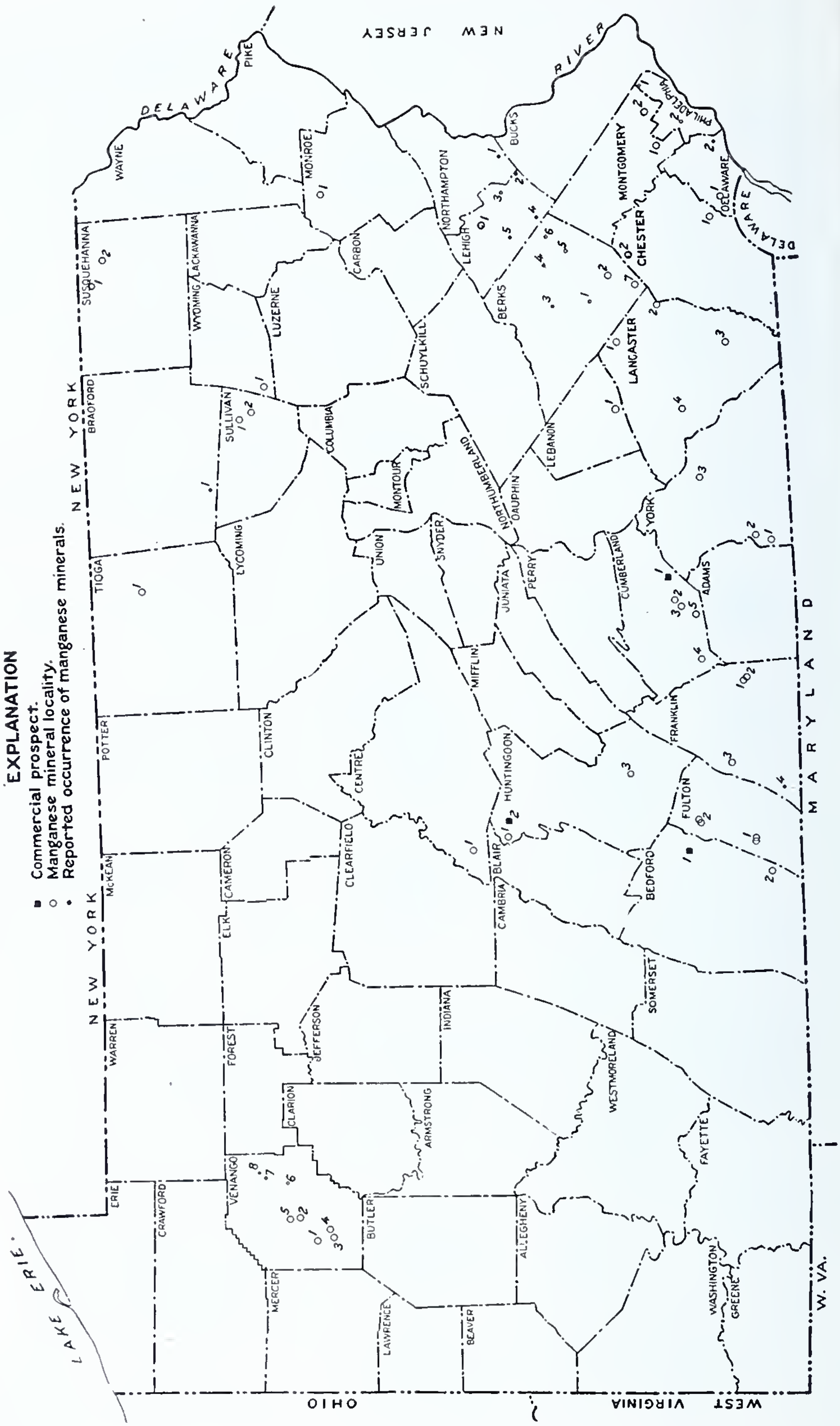
Manganese mineral localities

Locality	Associated rock[1]	Type Occurrence	Prospect[2]
Bedford County			
Sherman Valley (1)	Discussed under	commercial possibilities.	
McKees Gap (2)	Catskill	Stains, nodular	B
Berks County			
Morgantown Road (1)	Tomstown	Residual, nodular	B
Birdsboro (2)	Triassic ss	do	B
Maiden Creek (3)	Tomstown	do	B
Lyons (4)	do	do	B
Manatawyn (5)	do	Residual, bedded	B
Gehman tract (6)		Assoc. with iron ore	B
Joanna Station (7)	Triassic ss	Replacement	B
Bradford County			
Barclay basin (1)	Mauch Chunk	Residual, nodular	B
Centre County			
Wrye Bank (1)	Gatesburg	Resid., nod. & bed.	A
Chester County			
Sharpless farm (1)	Gneiss	Residual	B
French Creek (2)		Assoc. with iron ore	B
Cumberland County			
Reading Banks-White Rocks	Discussed under	commercial possibilities.	
McCarrick prospect (2)	Antietam	Residual, nodular	B
Wharton mine (3)	do	do	A
Clever Banks (4)	Tomstown	Assoc. with iron ore	B
Laurel Banks (5)	do	Residual, nodular	B
Delaware County			
Garnet mines (1)	Gneiss	Residual	B
Darby (2)	do	do	B
Franklin County			
English Bank (1)	Tomstown	Resid., nod. & bed.	A
Promise Bank (2)	do	do	B
Squire Stinger Bank (3)			
Little Cove Area (4)	Oriskany	Impreg. & replace.	B
Fulton County			
Needmore Area (1)	Catskill	Stains, nodular	B
Oregon Run Area (2)	Mauch Chunk	Residual, nodular	A

TABLE III (Continued)

Locality	Associated rock[1]	Type Occurrence	Prospect[2]
Huntingdon County			
East Pennington Bank (1)	Gatesburg	Resid., nod. & bed.	B
Huntingdon Furnace (2)	Discussed under	commercial possibilities.	
Orbisonia Area (3)	Oriskany	Impreg. & replace.	B
Lancaster County			
East Cocalico Twp. (1)	Ordovician ls.	Residual	B
Beartown (2)	do	do	B
Quarryville (3)	do	do	B
Silver Spring (4)	do	Resid. with iron ore	B
Lebanon County			
Cornwall (1)		Assoc. with iron ore	B
Lehigh County			
Ironton Banks (1)	Ordovician ls.	Resid., nod. & bed.	B
Wharton mine (2)	Antietam	Assoc. with iron ore	B
Emaus mines (3)		Resid., nod. & bed.	B
Alburtis (4)	Tomstown	Assoc. with iron ore	B
Fogelsville (5)	do	do	B
Monroe County			
Tobyhanna Area (1)	Pocono	Residual & bogs	B
Montgomery County			
Spring Mill (1)	Gneiss	Residual	B
Edge Hill (2)	do	do	B
Northampton County			
Saucon Twp. (1)	Tomstown	Residual, nodular	B
Philadelphia County			
Pennypack Creek (1)	Gneiss	Residual, nodular	B
Fairmount Park (2)	Recent drift	Bedded	B
Sullivan County			
Dempsey Bog (1)	Pocono	Bog	B
Lope (2)	Underclay	Impreg. & replace.	B
Susquehanna County			
Great Bend (1)		Bog	B
Susquehanna (2)		do	B
Tioga County			
Mansfield Area (1)	Chemung	Impreg. & replace.	B
Venango County			
Victory Hollow (1)	Mississippian	Bog	B
Brundred Lease (2)	do	do	B
River Ridge (3)	do	do	B
Kennerdell (4)	do	do	B
Bullion Hollow (5)	do	do	B
Wyoming County			
Dutch Mountain (1)	Pocono	Impreg. & bogs	B
York County			
Louis Delone Bank (1)	Ordovician ls.	Resid., with iron ore	B
Haldeman & Bechtel Banks (2)	do	Assoc. with iron ore	
Smyser Bank (3)	do	do	B

[1] See Table 2.
[2] A=worth prospecting; B=not worth prospecting.
Abbreviations: Nod.=nodular, resid.=residual, bed.=bedded, impreg.=impregnation, replace.=replacement.


EXPLANATION
Commercial prospect.
Manganese mineral locality.
Reported occurrence of manganese minerals.
NEW YORK
NEW JERSEY
DELAWARE
RIVER
LAKE ERIE
OHIO
WEST VIRGINIA
W. VA.
MARYLAND
DELAWARE
PIKE
WAYNE
SUSQUEHANNA
WYOMING
LACKAWANNA
MONROE
CARBON
LUZERNE
NORTHAMPTON
BUCKS
LEHIGH
BERKS
MONTGOMERY
PHILADELPHIA
CHESTER
SCHUYLKILL
LANCASTER
LEBANON
COLUMBIA
SULLIVAN
BRADFORD
TIOGA
LYCOMING
MONTOUR
NORTHUMBERLAND
DAUPHIN
UNION
SNYDER
JUNIATA
PERRY
CUMBERLAND
YORK
ADAMS
MIFFLIN
FRANKLIN
FULTON
HUNTINGDON
BLAIR
BEDFORD
CENTRE
CLINTON
POTTER
McKEAN
CAMERON
ELK
CLEARFIELD
CAMBRIA
SOMERSET
INDIANA
JEFFERSON
FOREST
WARREN
WESTMORELAND
FAYETTE
ARMSTRONG
CLARION
VENANGO
CRAWFORD
ERIE
BUTLER
ALLEGHENY
MERCER
LAWRENCE
BEAVER
WASHINGTON
GREENE

SHERMAN VALLEY AREA

Location and General Description

Sherman Valley, also called Ground Hog Valley, is in Bedford County, six miles northeast of Everett and four miles south of Hopewell. Two miles east of Cypher Station in the southwestern part of Sherman Valley, manganese ore and manganiferous iron ore have been produced during several short intervals through a period of at least 50 years.

About 1890 a company, organized by several men then actively engaged in the operation of the nearby Riddlesburg Furnace, drove an untimbered drift and sank a shaft upon the property. The drift encountered no ore, but the company is reported to have smelted some ore from the property at the furnace.

Another group of men sank a shaft in 1910, but no ore was recovered. The present owners drove a timbered slope in 1919 and operated off and on for four years. The slope, exposed by the present open cut, trends N27°E, has an inclination of 12 to 14 degrees, and a length of about 70 feet. It is in ore all the way. The open cut was dug in December 1940 and an ore face 6 feet high and 30 feet long was developed above the old slope. The most recent operations, in June 1942, have resulted in a ragged, slumped face, so that little ore can be seen in place.

Approximately 600 tons of ore have been mined from the property since it was first worked. There is record of shipment of 400 tons between 1919-1923, 100 tons in 1940 and 25 tons of high grade ore in June 1942.

GEOLOGY

The rock of the Sherman Valley area are all sedimentary of late Paleozoic age. They include the Portage and Chemung brown shales and sandstones and the Upper Devonian Catskill red beds, the Mississippian Pocono sandstone and Mauch Chunk red shale, and the coal-bearing Pennsylvanian Pottsville and Allegheny formations in the Broad Top coal field. The total thickness of sedimentary rocks in this area is about 9,200 feet. The rocks are all folded, but not metamorphosed. The axis of the Broad Top basin, including Rays Hill and Sherman Valley on the flanks, plunges about 18° toward N.25°E. This plunge causes the Pocono sandstone in Rays Hill to change strike sharply from N20°E to N65°E. These two trends are the most common in the region, though the rocks strike at all angles between the two.

It is necessary to describe only the Mauch Chunk and Pocono formations of the Mississippian, since these two underlie the flanks and floor of Sherman Valley where the ore occurs.

Pocono formation.—The basal Mississippian Pocono formation overlies the Devonian Catskill beds. It holds up Rays Hill and Sideling Hill surrounding the Broad Top coal field. The Burgoon sandstone at the top is 200 feet thick, massive bedded, coarse-grained, and tan to yellowish-white. With the darker-colored basal member, the Berea sandstone, and two other shale and sandstone members, the total thickness is between 1,100 and 1,200 feet.

Mauch Chunk formation.—The Mauch Chunk formation disconformably overlies the Pocono sandstone, the Loyalhanna limestone being absent in this region. A soft, thin-bedded and finely laminated, locally sandy, red shale, with limestone lenses in the basal 100 feet, the Mauch Chunk formation is approximately 1,000 feet thick in this region. The lowermost limestone, the Trough Creek member, is locally 25 feet thick. The limestone lenses are both grey crystalline and red crystalline. Manganese oxide ore is limited to the basal part of the formation.

STRUCTURES

The Sherman Valley area is part of the Ridge and Valley province of linear folds trending generally northeast-southwest across Pennsylvania. It is situated on the southeast flank of an assymetric syncline which plunges northeast. The axial plane of the fold strikes N.26°E., dips 70°W. Fracture cleavage, which is nearly an axial plane cleavage, is well developed in the Mauch Chunk shale and also strikes N.26°E., dips 70°W. In the steep northwest limb of the fold, the beds strike N.20°E., dip 50°-80°E; on the gentle southeast limb they strike N.65°E., dip 15°-45°N. The plunge of the fold at its nose in the southwestern part of Sherman Valley, measured as the intersection of bedding and cleavage, is 15°-20°NE.

Joints include a longitudinal set which have the same strike as the beds and a cross joint set which strikes at right angles to the bedding. The former dip at an angle of 90 degrees to the dip of the beds; the latter have essentially vertical dips and cut directly across both the Pocono and Mauch Chunk formations. Observed and measurable faults are a reverse fault in the Pocono sandstone and a normal cross fault in the Mauch Chunk shale. The occurrence of other cross faults of small displacement is inferred.

ORE DEPOSITS

GENERAL FEATURES

Manganese ore occurs chiefly as a replacement of the shale beds in the basal fifty feet of the Mauch Chunk formation. The areal geology in the immediate vicinity of the Sherman Valley open cut is shown in Figure 2.

In the Sherman Valley open cut are two main "beds," both essentially parallel with the bedding of the shale, and dipping 15°-20° northwest. The ore beds are separated by 15 feet of shale, which is stained black by films of manganese oxide on joint and bedding surfaces. Stringers of oxide less than one-quarter inch thick occupy some of the joints.

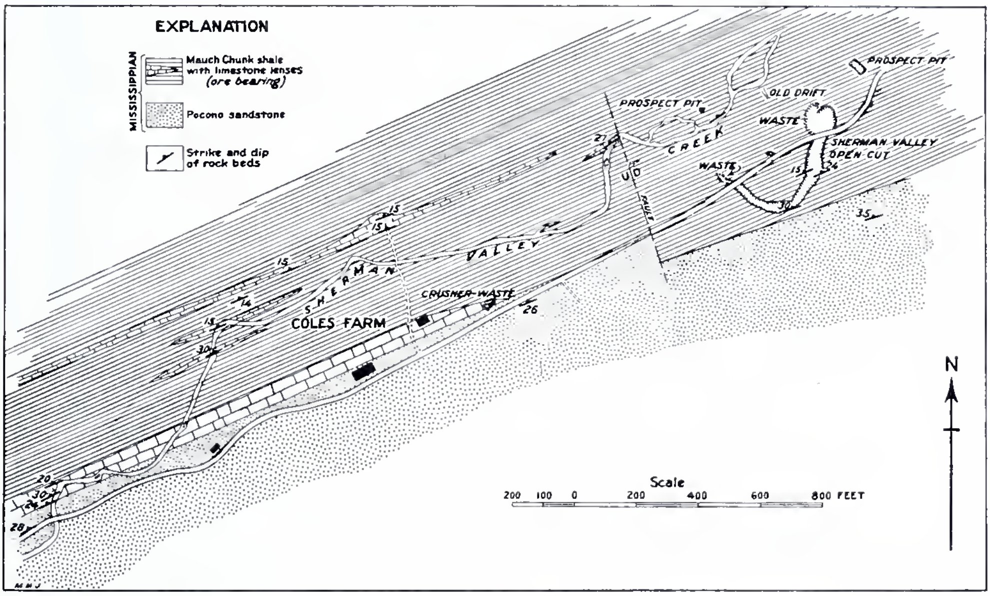


FIGURE II

Geology around Sherman Valley open cut

The lower ore bed averages 4 feet and ranges from 3 to 6 feet in thickness. It is dark brown to black, blocky manganiferous iron ore with an average manganese content of 10 percent.[1] The upper bed averages one foot and ranges from one-half inch to three feet in thickness. It is not nearly as uniform in thickness as the lower bed and swells and pinches, cutting across the bedding of the shale where it thickens. It is hard, steel-blue manganese ore with a minimum average manganese content of 45 percent. Many analyses show 50 percent and more of manganese.

A 70-foot slope from the floor of the open cut is in the lower bed of ore. The slope is slightly more than 6 feet high and most of it is in ore.

[1] Figures based on analyses of shipments of run-of-mine ore.

Ore minerals.—The ore minerals are oxides of iron and manganese.

The chief manganese mineral may be called by the common name of psilomelane.[1] It is typically dense and steel-blue, has a sub-metallic luster, a hardness of 5 to 6, a sub-conchoidal fracture, a black streak with a brownish tinge and a specific gravity of 4.28.

The ore takes several forms. It may be compactly bedded and massive, or individual beds, averaging two inches in thickness, may be "split" in the middle with botryoidal growths approaching each other from top and bottom. Most of the botryoids are very minute; they range up to one-quarter inch in diameter. There is no measurable difference in size between the botryoids on the top and bottom. There are all gradations between solid, massive beds with obscured botryoidal structures and opened, or split, beds with prominent irregular botryoidal surfaces. The central portion of some of the dense beds of psilomelane is softer and black. These zones, usually one-half to one inch thick, are alteration zones consisting of pyrolusite (MnO_2).

Thin stringers of psilomelane, iron oxide, and soft, black manganese oxide occupy some of the joint planes in the shale. The shale between the two ore beds is cut up by these stringers; several extend from one ore bed to the other.

In addition to psilomelane and the pyrolusite in the center of altered ore beds, the manganese oxide minerals include wad. It occurs as a few small masses in the residual mantle overlying the red shale and as small stringers and films of oxide which fill and cover joint and bedding planes in the shale. It is clearly later than psilomelane.

The iron oxide is of two types. Primary iron oxide in the Mauch Chunk shale is deep red-brown and occurs as thin laminae, .01mm and less thick, and as cementing material in the shale. Secondary iron oxide, which is abundant in the lower ore bed, is brown and has replaced sericite, primary limonite, and some of the quartz.

Gangue minerals.—The most abundant gangue mineral is quartz, which is the mineral of the host rock most resistant to replacement. Less abundant gangue minerals are sericite, carbonate (calcite), orthoclase, kaolinite, and a few scattered grains of zircon and primary rounded grains of chalcopyrite, which is very strangely associated with the shale.

Gangue consists for the most part of unreplaced masses of red shale.

Paragenesis.—The mineral sequence in the Sherman Valley area, based mainly on microscopic study of ore from the Sherman Valley open cut, is:

1. Primary bedded red shale, consisting mainly of quartz, sericite, and primary limonite, and containing orthoclase, kaolin, zircon, and chalcopyrite
2. Limonite—practically contemporaneous with 3
3. Psilomelane

[1] The mineral is another manganese oxide, similar to psilomelane, but having different chemical composition and molecular structure. It is unnamed.

4. Second generation psilomelane
5. Pyrolusite—alteration by primary solutions
6. Soft black oxides (wad)—surficial weathering.

The paragenesis of the minerals is clean-cut except for limonite and first generation psilomelane. These two are practically contemporaneous, as indicated by conflicting age relations in ores physically near each other.

GENESIS

Nothing definite can be stated concerning the ultimate source of the manganese in the ore minerals other than that it is stratigraphically higher than the ore-bearing beds, and the manganese is of supergene origin.

The manganese and iron oxides are both typical of surficial mineralization, and it seems likely that the minerals were never formed at a depth of more than several hundred feet. Likewise, the ore-bearing solutions, which were probably percolating waters, were not hot; they may have been slightly warm at the greatest depths.

Structural control by bedding and compositional control by the minerals of the shale governed the replacement processes. The solutions moved down the dip of the beds near the contact of the Mauch Chunk shale with the Pocono sandstone and, to a much lesser extent, across the bedding along joints. The manganese was most likely in the soluble form of the carbonate or bicarbonate. Sericite, primary limonite and, to a much lesser extent, the quartz of the shale were replaced by manganese oxide. Solution of the shale evidently proceeded faster at some places than replacement, as shown by the "split" ore, in which the shale is absent from the middle opening and botryoidal clusters have partly grown toward each other by precipitation from solutions which migrated through the channel.

The channel-like path of the solutions, at least during later stages of the ore formation, is also clearly shown by alteration of massive beds, in the central channel zone, to pyrolusite.

The composition of the solutions evidently changed during the processes of replacement and deposition and the change affected the ratio of the iron—manganese content especially. Why the manganese-rich ore lies above the iron-rich ore, when the solubility of manganese is greater and most occurrences are of the opposite nature, is not clear.

The time of formation of the ore can only be speculated upon. The probable fact that the ore formed at shallow depth and the knowledge that this area was peneplained in Tertiary time, thus removing great thickness of overlying rocks and possibly also serving to concentrate residually the manganese and iron oxides in the weathered zone of the peneplained surface, suggests a middle or late Tertiary time. Continued accumulation, and partial alteration, of the ore in Recent time is probable.

SIZE AND GRADE OF THE ORE BODY

Without further development work on the ore body it is impossible to estimate the tonnage fairly. The nature of the ore indicates that

the body is of a "local" character. Assuming an average thickness of 2 feet of ore, an extension of 200 feet along the strike and 300 feet down the dip, there is an approximate 12,000 tons of ore which could be proved by a limited amount of development work.

The grade of the manganese ore is good. By selective mining and hand picking a grade of better than 45 percent Mn can be maintained. The manganese content of run-of-mine ore is fairly constantly 10 percent. The iron content of the high grade ore is not objectionable. The silica content is locally high, but the average is not high enough to make the ore unsalable. The phosphorous content is fairly constant at about 0.25 percent. Representative analyses appear in Table 4.

READING BANKS AREA

Location and General Description

Reading Banks and White Rocks are two miles southeast of Boiling Springs, along the northern flank of South Mountain, in Cumberland County. Most of the property is owned by the Philadelphia and Reading Coal and Iron Co. of Philadelphia. The old pits are accessible from Boiling Springs by gravel and dirt roads, and the vicinity of White Rocks is accessible by path; an old dirt road is impassible through disuse.

Pits were dug in the vicinity of Reading Banks more than a century ago. Operations by the Philadelphia and Reading Coal and Iron Co. began in 1872 and, by a combination of stripping and underground operations, they removed about 700,000 tons of ore in the next 20 years.

In the fall of 1939 the firm of Leghorn and Mitchell, of Boston, Mass., began prospecting in the vicinity of Boiling Springs for manganese ore. Stripping operations began in May 1940 and continued till the end of November. About 1,500 tons of manganiferous iron ore were removed to a stock pile and 3 carloads of ore were shipped to a smelter in September and November. A large steam shovel and, later, a dragline were used to move the clay and ore, which was trucked to dumps and stock pile.

Since 1940 there has been no activity.

GEOLOGY

The rocks of the area belong to two large groups. Pre-Cambrian crystalline rocks of igneous origin comprise the core of South Mountain. Lower Paleozoic quartzites and limestones partly overlie the older crystalline rocks along the flanks of the mountain and floor the Great Valley to the north.

In the order of stratigraphic sequence, the Weverton sandstone (Loudon formation), Montalto quartzite, Antietam quartzite, Tomstown dolomite, and Waynesboro formation unconformably overlie the pre-Cambrian rocks. The first three members of this group form a series of quartzitic beds more than 3,000 feet thick. The Tomstown dolomite and the sandy Waynesboro formation having a thickness of about 1,000 feet are overlain by the great series of Upper Cambrian and Ordovician limestones more than 4,000 feet thick.

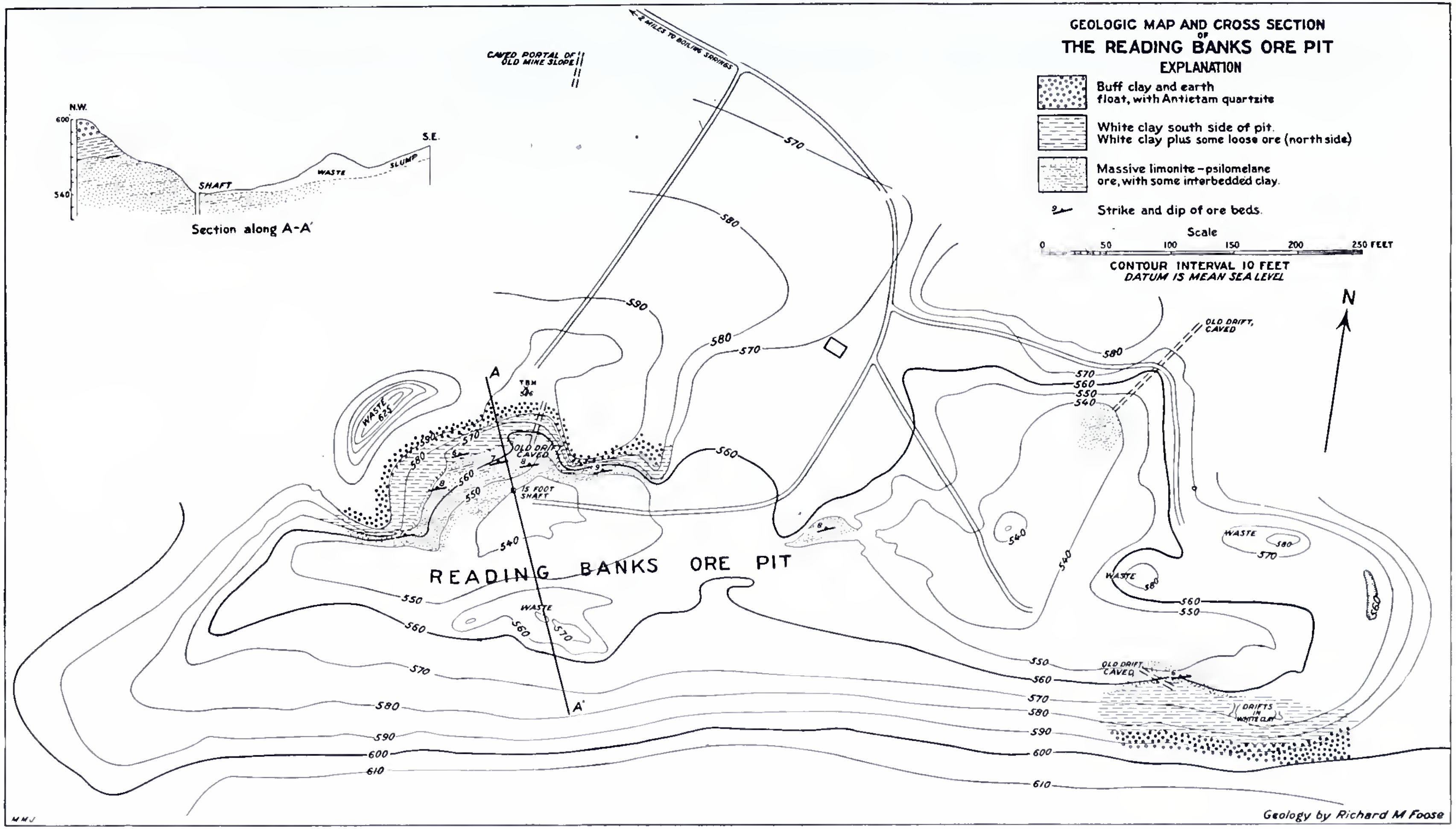


Figure 3. Geology of the Reading Banks ore pit

The Antietam and Tomstown formations, both of Cambrian age, are the rocks with which manganese ore is associated.

Antietam sandstone.—The Antietam sandstone, or quartzite, is the upper member of the quartzore formations that make South Mountain. It is a relatively pure, hard, coarse-grained, white and grey, quartzitic sandstone, bearing numerous Scolithus tubes, and weathering, especially in its upper part, to a buff sand. The upper part locally carries manganese oxide ore. Exposures of the rock are poor, and it is impossible to measure the thickness of the formation. A general estimate of its thickness in this area is about 600 feet.

Tomstown dolomite.—The Tomstown dolomite overlies the Antietam sandstone. It consists of a lower part of coarse grey dolomite with interbedded siliceous sericitic shale, a middle part of interbedded dark-blue limestone and thin shale, and a top part of purer grey and blue dolomite and limestone with fewer shaly beds. There are no outcrops of the formation in the immediate vicinity. It is covered by a heavy mantle of residual soil and clay. The clay is especially well developed where the basal part of the formation is very shaly, and it is this part that bears the manganese ore.

Structure.—South Mountain is an anticline which plunges along its axis toward the northeast and disappears under the lower Paleozoic limestones and shales of the Cumberland Valley. The strike of the mountain and of all the formations which flank it is N.62°E. Its northern flank is folded at several places so that the Cambrian formations form several sharp re-entrants along the trend. One of these is at White Rocks, one mile east of Reading Banks. These re-entrants are both structural and topographic. In addition to this subsidiary folding which has caused the formation of small synclinal areas plunging away from the central mass, there are several inferred faults. These, too, have caused topographic re-entrants into the mountain.

The lower Paleozoic formations dip 5°-30° NW, and over large areas the Antietam sandstone probably forms the dip slope of the northern flank. Reading Banks is situated far down the slope of this north flank at an elevation of 600 feet, where the beds dip about 10°NW.

ORE DEPOSITS

GENERAL FEATURES

Manganese ore and manganiferous iron ore occur in three ways at the Reading Banks and in the re-entrant near White Rocks, one mile farther southeast:

1. Solid mixed manganese-iron oxide ore with a slumped bedded character, containing thin interbeds of white and yellow clay, situated near and at the base of the Tomstown formation in contact with the Antietam sandstone.
2. Nodular psilomelane and limonite in residual yellow clay slightly above the base of the formation.
3. Thin beds and stringers of psilomelane and limonite in tan, yellow, and black clay, about 100 feet above the base of the formation.

In the Reading Banks pit the solid ore is visible at four places, all of them near the bottom of the pit (Fig. 3). The best exposure is on the north face near the west end of the pit where the ore forms a face 35 feet high and a bench at the top of it. The ore is interbedded with clay, and the entire face has a bedded character. The beds dip 6°9°NW.

Ore apparently floors the entire pit and is exposed at several places along the sides. The overlying wash ore is not as persistent. The grade of the solid ore is 5 to 8 percent of manganese.

Test pits sunk in 1940 revealed nodular ore (type 2) in the vicinity of White Rocks. The entire area is covered with sandstone talus blocks of fair size, so it is difficult to say whether the ore has slumped down the side of the mountain or is in place. The lack of float in the lower half of several 10- and 12-foot pits, however, suggests that the ore is in place. The ore is nodular psilomelane and nodular limonite. The grade of the manganese oxide nodules is more than 45 percent of manganese.

MINERALOGY

Ore minerals.—The manganese and the iron minerals are all oxides. The manganese minerals include psilomelane, manganite, pyrolusite, and wad.

The chief mineral is psilomelane ($MnO \cdot (Mn,K)O \cdot n\, H_2O$). In both the nodular form and the bedded form it has the same physical properties. It is a dense, blue-black to steel-blue mineral having a hardness of 6.5, a sub-metallic luster, a black streak with a brown tinge, and a specific gravity of from 4.29 to 4.43.[1]

Manganite ($Mn_2O_3 \cdot H_2O$) occurs in the ore at Reading Banks as small veinlets, not more than one-eighth inch thick, which cut across limonite. Since manganite is frequently a hypogene mineral, it is possible that the presence of cross-cutting manganite veinlets indicates late hypogene activity.

Pyrolusite (MnO_2) and wad, the soft, black aggregation of manganese oxides, occur as alteration minerals, associated in very small amounts with psilomelane. Pyrolusite has also formed by the alteration of manganite, retaining the prismatic form of the manganite in small veinlets. Wad is superficial. It occurs most abundantly in the black clay associated with the wash ore above the solid ore at Reading Banks.

Iron oxide occurs in three different generations and is of three distinct physical types.

1. Early, rust-colored amorphous iron oxide.
2. Later, dark brown and black amorphous iron oxide which usually replaces most of the first type.
3. Late, crystalline golden-colored goethite which selectively replaces certain colloform bands of iron or manganese oxide. This type is rare. It was not recognized megascopically.

[1] Gravity by Jolly balance. Bedded ore=4.29; nodular ore=4.43.

Gangue minerals.—The chief gangue mineral at Reading Banks is quartz. It is clear and sub-angular, averages .02 mm. in diameter, and locally comprises as much as 10 percent of the ore mass.

Accessory gangue minerals include zircon and tourmaline. Masses of clay and of brecciated Antietam sandstone comprise a large portion of the gangue locally. These usually can be easily removed by crushing and washing.

Paragenesis.—The sequence of events at Reading Banks is confused in some of its details, but the general outline is simple:

1. Replacement of yellow, arenaceous, Tomstown clay and part of the Antietam sandstone by first generation rust-colored limonite.
2. Fracturing and brecciation of the iron oxide ore mass.
3. Replacement of the brecciated mass by second generation black and dark brown limonite.
4. Replacement by veinlets and larger masses of psilomelane.
5. Replacement by veinlets of manganite.
6. Replacement of psilomelane and manganite by crystalline geothite.
7. Alteration of manganite to pyrolusite and of psilomelane to pyrolusite and wad.

GENESIS

The exact source of manganese and iron is not known. Since the ore is supergene, it is somewhere in the sedimentary series starting with the Tomstown formation and including the overlying beds. Logically it is limited to the Tomstown and the immediately overlying Cambro-Ordovician limestones and does not include the beds of late Ordovician age and those above it. Logically, too, the main source is most likely in a clastic series of beds which would contain mineral impurities rather than in relatively pure, chemically precipitated limestones. Therefore, the semi-clastic beds of the Tomstown formation, which form a transitional sequence from the clastic Antietam sandstone below to the nearly pure, thick limestones above, are the most probable source.

The manganese was carried downward as a minor constituent of predominantly iron-bearing waters in a soluble form, probably the carbonate or bicarbonate. These solutions penetrated the clay and dispersed in all directions, controlled chiefly by laminae and cracks in the clay and, ultimately, by the very resistant, less pervious medium of the underlying Antietam sandstone. Dispersion of the solutions in the clay and accumulation at the base of the clay overlying the sandstone was accompanied by replacement of the host clay by the oxides of both iron and manganese.

SIZE AND GRADE OF THE ORE BODY

The ore body at Reading Banks is, of course, not limited to solid ore. Practically speaking, it is all of the clay at the base of the Tomstown formation, which includes enough ore to be mined profitably. At the Reading Banks pit the amount of ore removed is about 700,000 tons. The volume ratio of ore to clay which has been moved is about

2½ parts of clay to 1 part of ore. On the basis of exposures of the ore and the limited exploration work conducted at Reading Banks during 1940, it is estimated that at least 150,000 tons of manganiferous iron ore is within easy access from the old workings.

The ore body in the vicinity of White Rocks is of much more uncertain character. Knowledge of this body is limited to about 10 shallow test pits. The volume ratio of clay to ore in the pits averaged about 6 to 1. The ratio of manganese oxide to iron oxide is about 1 of manganese to 2 of iron; locally it is 1 to 1. Assuming the presence of nodular ore to a depth of 20 feet, a rough estimate of the explored reserves in this area would be 50,000 tons of mixed manganese-iron ore. With a ratio of 1 part manganese to 1 part iron, 25,000 tons of manganese ore may be expected. The size of the body could be 10 times as great, since an area that large lies within the structural and topographic re-entrant northeast of White Rocks. However, it has not been properly explored to determine the possibility.

The analyses in Table 4 indicate the general chemical nature of the ore from Reading Banks and the vicinity of White Rocks. The phosphorous content is very high and would probably cause prohibitive metallurgical difficulties. The low percent of manganese and the high percent of phosphorous at Reading Banks is very unfavorable. A limited amount of prospecting by drill holes down the dip, north of the pit, to determine the character and extent of ore at depth may be warranted.

The high manganese content and lower phosphorous content of the ore in the vicinity of White Rocks would justify careful exploration and sampling of ore in that area by pits and trenches. The features to be determined are:

1. Depth of nodular ore horizon.
2. Volume ratio of clay to ore.
3. Volume ratio of manganese to iron ore.
4. Chemical composition of ore with relation to its location.

HUNTINGDON FURNACE BANKS

The Huntingdon Furnace iron ore banks are along the southern slope of Dry Hollow Ridge, three miles south of Warriorsmark, in Huntingdon County. In the weathered clay horizon of the Cambrian lower Gatesburg formation, nodular and crudely bedded psilomelane is associated with iron oxide (limonite). The banks are slumped and partly filled with water. Most of the property is owned by the Sand and Feldspar Company (Baltimore, Md.), which is now mining white clay.

The Gatesburg formation, composed of alternating sandy and dolomitic beds, has weathered to a residual sandy clay which carries the ore. There are no outcrops of the formation in the immediate vicinity, but the structure is revealed by the ore occurrence. Thin-beds of iron and manganese oxide, replacements of original dolomitic beds, dip gently toward the southeast all along the northwest side of

the pit. Besides the bedded ore, nodules of limonite and psilomelane are locally abundant in the clay.

The ore is of good grade, much of it being 45 per cent manganese. The surface occurrence of nodules indicates an area more than 1,000 by 350 feet which may be ore bearing. Prospecting should be done to determine the depth and area of ore occurrence and the ratio of high-grade manganese ore to the embodying clay. There may be 25,000 tons of rather easily recovered manganese ore on this property.

TABLE IV

Analyses of Pennsylvania manganese ores

Locality	Character of sample	Mn	Fe	SiO_2	P
Sherman Valley[2]	R. R. car	45.06	2.13	17.18	0.263
do[2]	washed, crushed	50.43	3.13	5.09	0.32
do[2]	do	50.71	1.40	1.90	0.25
do[2]	lump	42.09	7.06	9.48	0.27
do[2]	do	44.46	1.65	17.09	0.24
do[1]	run-of-mine, R. R. car	21.49	16.07	——	——
Reading Banks[1]	R. R. car	13.69	33.19	——	——
do[1]	do	9.33	40.39	——	——
do[2]	lump	46.36	11.11	——	0.42
do[2]	do	47.31	9.21	1.28	0.26
White Rocks[3]	nodule	41.80	19.60	6.67	0.63
Huntingdon Furnace[2]	stock pile	36.31	8.82	18.10	0.08
McCarrick Prospect[3] (Cumberland Co.)	lump	47.24	1.20	1.80	——
Wharton Mine[3] (Cumberland Co.)	do	39.34	9.00	9.62	——
English Bank[3] (Franklin Co.)	do	15.99	30.40	——	——
Laurel Banks[3] (Cumberland Co.)	do	25.34	30.10	——	0.056

[1] Analyst, E. J. Lavino Co.
[2] Analyst, Alan Wood Co.
[3] Analyst, Pittsburgh Testing Laboratories.